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(12) UK Patent Application (19) GB (11) 2 315 288 (13) A

(43) Date of A Publication 28.01.1998

(21) Application No 9618533.5

(22) Date of Filing 04.09.1996

(30) Priority Data
(31) 962958 (32) 15.07.1996 (33) NO

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(51) INT CL[6]
E04B 1/98, E04H 9/10

(52) UK CL (Edition P)
E1D DF115 DLEQW2 D2141 D402 D505

(56) Documents Cited
GB 2002436 A

(58) Field of Search
UK CL (Edition O) E1D DCF DF115 DLEKMNV DLEQWNV
INT CL[6] E04B, E04H
ON-LINE: WPI

(54) **Explosion-resistant wall**

(57) An explosion resistant wall comprises a wall surface (1) of plate material which has corrugations with top surfaces (4) and bottom surfaces (3) which are parallel to the principal plane of the wall. Side surfaces (5) connect the top and bottom surfaces (4; 3) and form corners (7; 8) therewith. The corners (8) lying closest to the source of a potential explosion pressure (P) are reinforced by means of plate angles (9) which follow the form of the wall surface (1) in the corner portions. The wall surface (1) is put together from plate elements having partly overlapping surface portions (3) which form the surfaces (2) of the wall surface, said overlapping portions being welded to each other. The plate elements are also provided with reinforcing end plates (6), which likewise are welded to each other.

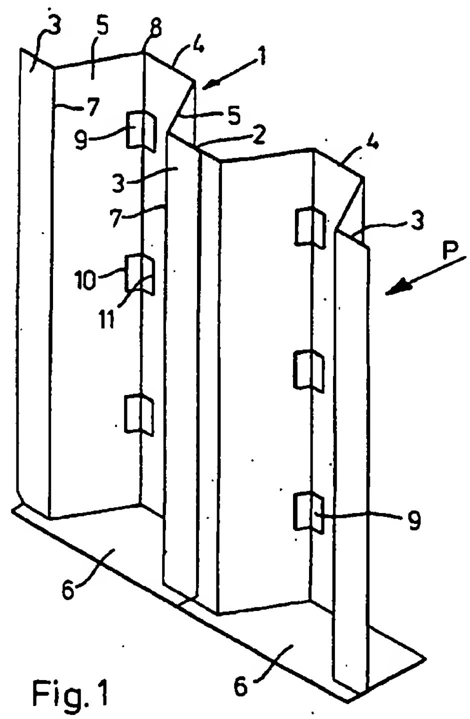

Fig. 1

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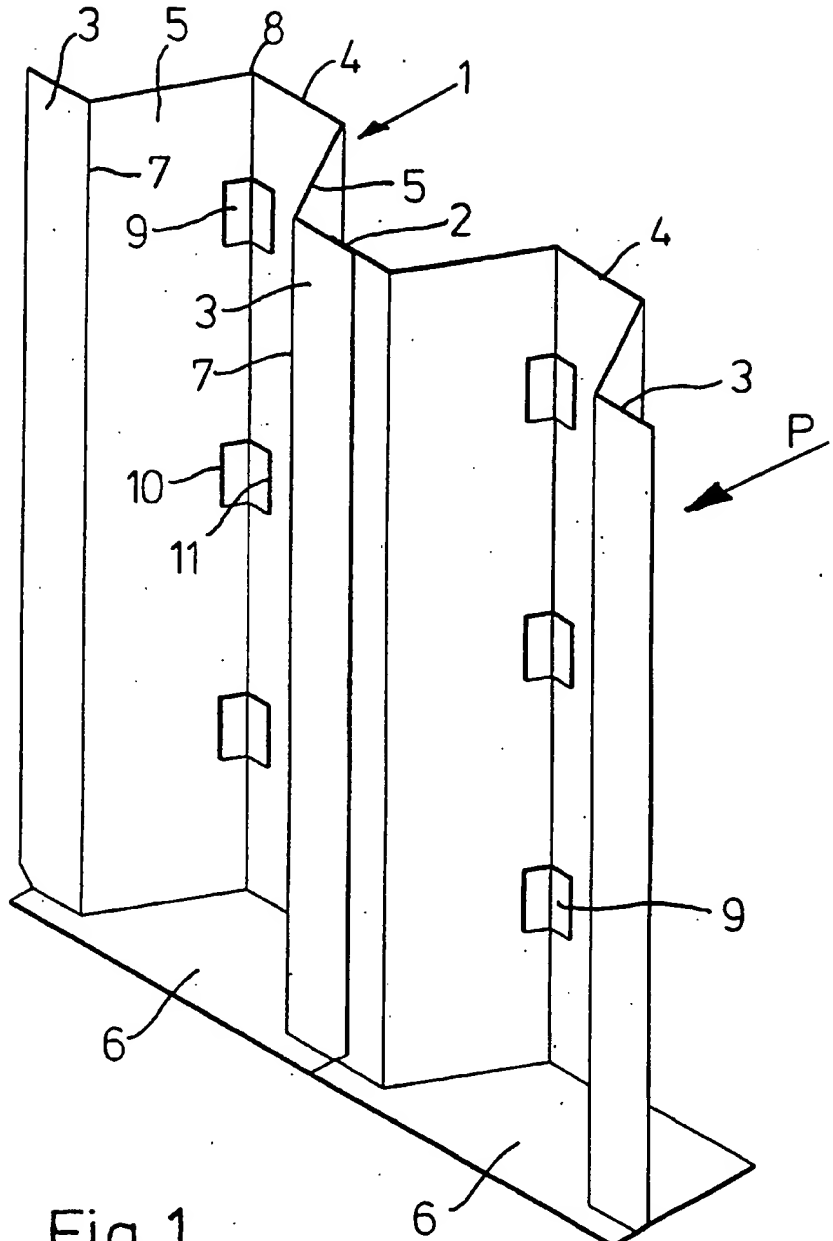

Fig. 1

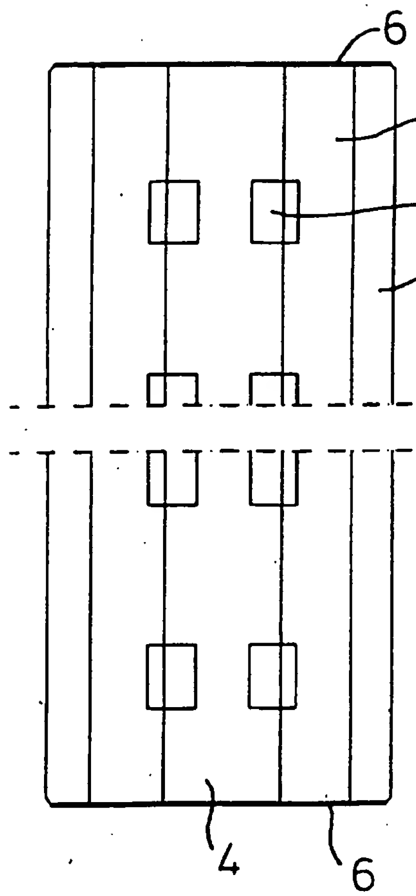

Fig. 3

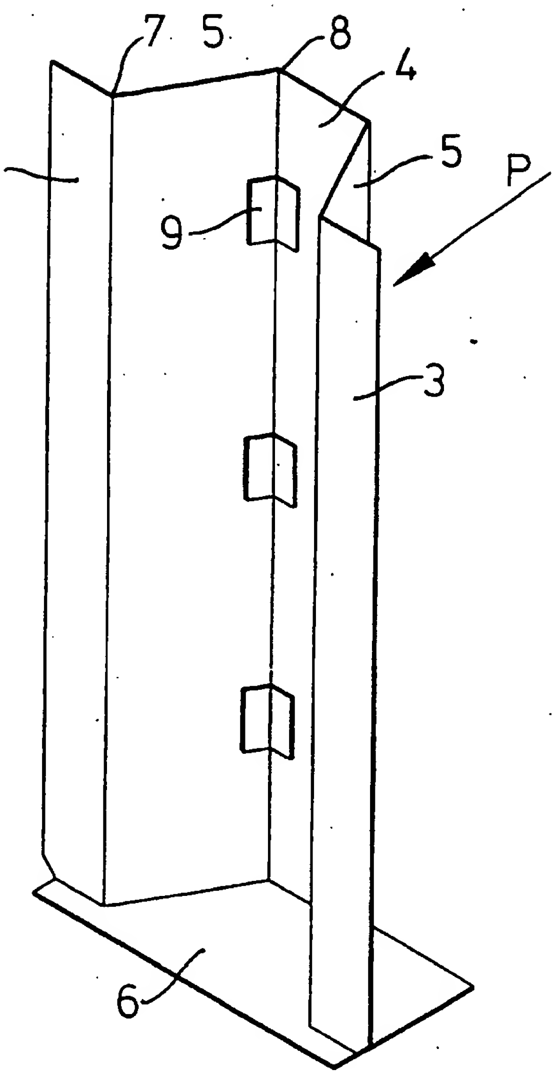

Fig. 2

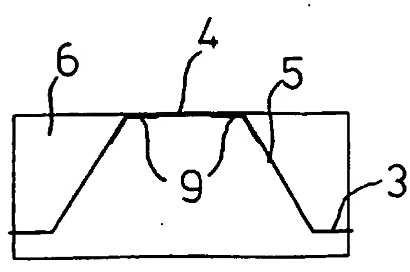

Fig. 4

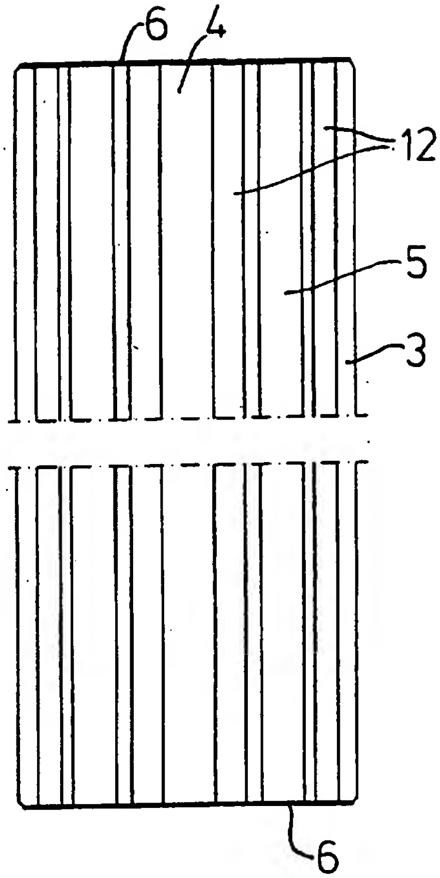

Fig. 6

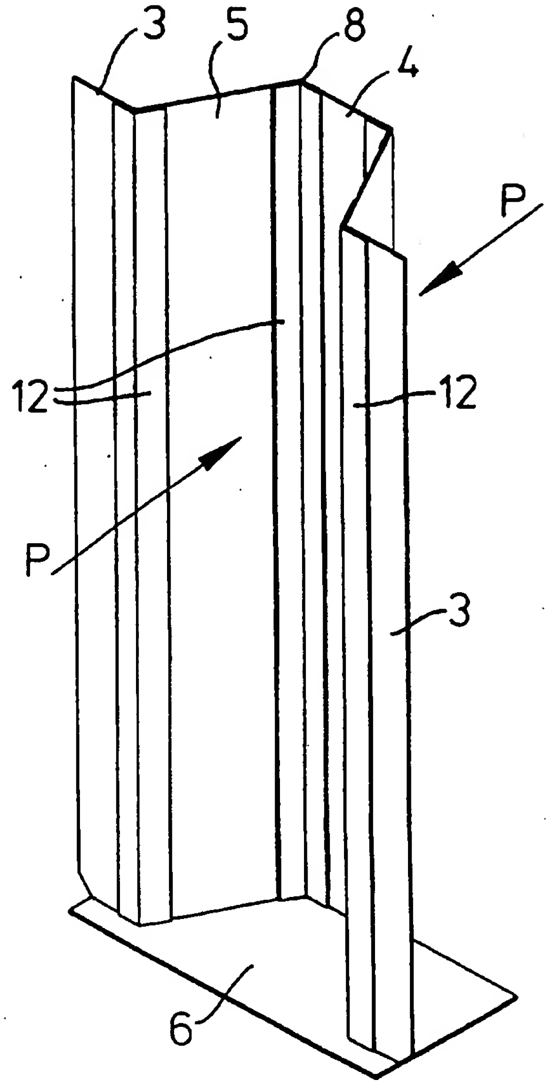

Fig. 5

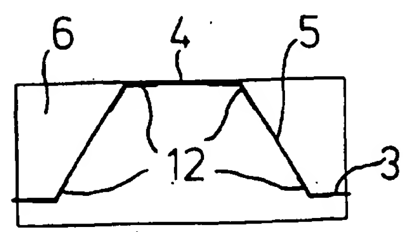

Fig. 7

EXPLOSION RESISTANT WALL

The present invention relates to an explosion resistant wall, comprising a wall surface of plate material having corrugations with top surfaces and bottom surfaces which are parallel to the principle plane of the wall and with side surfaces connecting the top and bottom surfaces and forming corners therewith, said wall surface on at least one of its sides being provided with reinforcement plates which along one of its side edges are joined to a side surface of the wall surface.

Such an explosion resistant wall is i.a. known from Norwegian patent No. 175 271. In this known wall the reinforcement plates are constituted by flat plate elements which are welded between opposite side surfaces of the wall on the side facing away from the possible explosion pressure. If the reinforcement plate extends in the entire height of the wall surface, a hollow space will be formed behind the reinforcement plate where condensation and corrosion may take place if the wall surfaces of the hollow space are not coated with a protective substance. The hollow space also becomes difficult to fill with insulation material. If this known wall is to be built so that it can withstand explosion pressure from both sides, it must be provided with reinforcements plates on both sides. This is disadvantageous from a production point of view because the plate first must be welded on one of the sides and thereupon turned around for welding on the other side. Furthermore, it will be difficult to upgrade a wall, which originally is installed for explosion pressure from one of the sides, to a wall which may take pressure from both sides because the wall will often be provided with insulation on the pressure side. The known solution also has the drawback that the material properties of the reinforcements plates cannot be optimally utilized.

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The purpose of the present invention is to provide an explosion resistant wall of the type described above which is not suffering from the above mentioned drawbacks and deficiencies.

This is obtained according to the invention by letting the reinforcement plates be constituted by a plate angle which along another of its edges is attached to a top or bottom surface of the wall surface and which follows the corner formed by the surfaces to which it is joined.

With such an arrangement the reinforcement plates will not form hollow spaces which must be insulated or protected due to the danger of condensation formation and, furthermore, they will not give rise to irregularities of any magnitude in the surface of the wall. In addition, reinforcement plates may be mounted at a later stage on those corners which were not so provided from the start if it should be desirable to upgrade a wall from one-sided to two-sided pressure loading. Since the reinforcement plates are plate angles which adjoin the corners they are mounted on, they may be arranged on one or the other or both sides of the wall. One has also found that the material properties of the reinforcement plates are better utilized so that weight is saved.

In order to provide a better understanding of the invention, it will be described more closely with reference to the exemplifying embodiments shown in the appended drawings, where:

Figure 1 is a perspective view showing part of a lower portion of an explosion resistant wall according to the invention,

Figure 2 shows a perspective part of a lower portion of a plate element entering into the wall on Figure 1,

Figure 3 is an elevation of the plate element shown in Figure 2,

Figure 4 shows a part of the plate element in Figure 2 in plan view,

Figure 5 shows a view similar to Figure 2 of an alternative embodiment of the plate element,

Figure 6 shows an elevation of the plate element of Figure 5, and

Figure 7 shows an elevation of the part of the plate element shown in Figure 5.

The wall portion in Figure 1 comprises a wall surface 1 of plate material which has corrugations having a top surface 2 consisting of two partly overlapping top surface parts 3 which are welded together, bottom surfaces 4 and side surfaces 5. The wall portion further comprises end plates 6 which are welded together.

The side surfaces 5 form top corners 7 together with the top surfaces 2 and bottom corners 8 together with the bottom surfaces 4. In the embodiment of the wall portion shown in Figure 1 and of the plate element shown in Figures 2-4, the bottom corners 8 are reinforced with plate angles 9, which along their longitudinal edges 10, 11 are welded to, respectively, the side surface 5 and the bottom surface 4 forming the corner. To obtain sufficient strength, it is usually not necessary to weld the angled transverse edges of the plate angles, but this may nevertheless be done in order to seal any gaps between the plate angles and the side and bottom surfaces. As shown, the plate angles 9 are shorter than the spacing between them, and they cover a relatively small part of the width of the side and bottom

surfaces. Nevertheless, the plate angles provide the desired increase in the bulging resistance of the wall surface 1 and lead to a considerable weight reduction with respect to the prior art.

As may be seen, the plate angles are arranged on the opposite side of the wall surface 1 with respect to the possible explosion pressure designated by the arrow P, namely in the bottom corners 8 lying closest to the potential explosion source. Anyhow, there is little or no reason for not arranging the plate angles 9 on the explosion side of the same corners.

Figures 5-7 illustrate an embodiment where the plate angles 12 extend over the entire length of the corners and where also the top corners 7 are provided with such plate angles. When all the corners are reinforced, the wall can withstand explosion pressure from both sides, such as suggested with the two opposed arrows P.

For the skilled person it will be clear that the present invention, which is especially well suited for walls in installations handling explosive fluids, for instance offshore platforms, may be modified and varied in a number of ways within the scope of the following claims. The reinforcement plates may advantageously be made of steel, but also other materials having sufficient fire resistance are contemplated, for instance composite materials based on phenolic plastic.

C L A I M S

1. An explosion resistant wall, comprising a wall surface (1) of plate material having corrugations with top surfaces (2) and bottom surfaces (3) which are parallel to the principle plane of the wall and with side surfaces (5) connecting the top and bottom surfaces (2; 3) and forming corners (7; 8) therewith, said wall surface (1) on at least one of its sides being provided with reinforcement plates (9, 12) which along one of its side edges (10) are joined to a side surface (5) of the wall surface (1),
characterized in that the reinforcement plates be constituted by a plate angle (9, 12) which along another (11) of its edges is attached to a top or bottom surface (2; 3) of the wall surface (1) and which follows the corner (7; 8) formed by the surfaces (5; 2, 3) to which it is joined.

2. An explosion resistant wall according to claim 1, characterized in that the plate angles (9) are joined to those corners (8) which are convex on the explosion side of the wall surface.

3. An explosion resistant wall according to claim 1, characterized in that all the corners (7; 8) of the wall surface (1) are reinforced with plate angles (12).

4. An explosion resistant wall according to claim 1 or 2, characterized in that the plate angles (9, 12) are joined to one and the same side of the wall surface.

5. An explosion resistant wall according to claim 4, characterized in that said side is the opposite one of the explosion side.

6. An explosion resistant wall according to claim 4, characterized in that said side is the explosion side.

7. An explosion resistant wall according to a preceding claim, characterized in that the plate angles (12) extend over the entire length of the corners (7; 8).

8. An explosion resistant wall according to one of claims 1 - 6, characterized in that each reinforced corner (8) is provided with a plurality of spaced plate angles (9).

9. An explosion resistant wall according to claim 8, characterized in that the spacing of the plate angles (9) is larger than their length.

10. An explosion resistant wall according to a preceding claim, characterized in that it is comprised by a row of plate elements each comprising a bottom surface (4), two side surfaces (5) and two top surface portions (3) having a width exceeding half of the width of the top surfaces (3), said plate elements preferably being provided with end plates (6).

11. An explosion resistant wall substantially as herein described with reference to, and as shown in any of Figures 1 to 4 or any of Figures 5 to 7 of the accompanying drawings.

The Patent Office

Application No:	GB 9618533.5	**Examiner:**	J D Cantrell
Claims searched:	1 - 11	**Date of search:**	25 September 1996

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.O): E1D: DF115. DLEQWNV,DLEKMNV,DCF

Int Cl (Ed.6): E04B, E04H

Other: ON - LINE : WPI

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
A	GB 2002436 A SCHIEBROEK	-

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
		E	Patent document published on or after, but with priority date earlier than, the filing date of this application.
&	Member of the same patent family		

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April 5, 1994

Cyclic Performance of Tall-Narrow Shearwall Assemblies

Alfred D. Commins and Robert C. Gregg[1]

Abstract

Tall, narrow wood shear walls with a 3.5:1 aspect ratio were tested to full design load under cyclic loading for 90 cycles and to 140% of design load for another 90 cycles. The testing was performed at 2 cycles per second and at 15 seconds per cycle. The performance of wall assemblies and attachment devices is discussed. Attachment devices currently available for construction were compared with an experimental device not considered practical for field installations.

Introduction

Plywood shear walls are commonly used to resist lateral forces typically encountered with wind or seismic events. Shear walls with an aspect ratio of 1.0 and lower have been studied and reported upon. Typically the studies factored out the deflection contribution from the connection hardware. The geometry of low aspect ratio shear walls is such that deflection of the attachment hardware will have minimal effect on the drift of the wall.

Conversely shear walls with a high aspect ratio can be greatly affected by panel geometry. Under load, small deflections anywhere in the system can result in substantial drift at the top of the wall.

Recently there have been industry discussions relative to tall narrow shear walls and the attendant attachment hardware. The discussions have centered on system performance under monotonic (Single Direction Static Loading) and dynamic (cyclic) loading.

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1 Alfred D. Commins, Manager, Research and Development, Simpson Strong-Tie;
Robert C. Gregg, P.E. Simpson Strong-Tie

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The tests outlined in this report were performed to explore the system performance of the walls and attachment devices when subjected to cyclic loading at 100% and 140% of the wall design load. The geometry of the system resulted in holdown loads that were 121% and 178% of the allowable hardware holdown loads. The hardware used for this testing was the Simpson Strong-Tie HD5A, an experimental "Rod Strap" and a Special HD5 made to be extremely rigid.

Aspect Ratio

The tests were conducted on wood shear walls with a 3.5:1 Aspect Ratio. The test walls were 96" high with a width of 27.5". Traditional testing has concentrated on walls with a width equal to the height(Aspect ratio of 1.0:1.0), typically with 8' X 8' panels The performance on 8' X 8' shear walls has been extrapolated to walls with higher aspect ratios. Currently the Uniform Building Code (1991 UBC Table 25-I)[2] allows aspect ratios up to 3.5:1. This ratio equates to 27.5" for 8' walls.

Shear walls with high aspect ratios compound the problem further because of the location of the attachment hardware. No indication is made as to where the holdown connections should be. In normal construction however, the connection hardware is placed on the inside of the wall. For example, for the Simpson HD5 and HD5A the offset from the face to the center of the attachment bolt is approximately 2". Added to the thickness of the framing members this moves the attachment point inboard some 5". The net effect of this inboard movement is to change the nominal aspect ratio of 3.5:1 to 4.27:1. This will effectively increase the load on the hardware some 22% over what might normally be assumed.

While shear walls are designed and installed to resist reversed cyclic motion, (such as that caused by earthquakes), no universally accepted standard test method exists to guide the research professional. Cycle speed, number of cycles, loading, rate of loading, displacement, data acquisition locations, data acquisition rates, and report output are only some of the variables that need to be considered. Because the problem is so complex, and because no community consensus has been reached there is no test standard.

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2 Uniform Building Code, UBC 1991, International Conference of Building Officials, Whittier, California

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Holdowns

The items that connect the shear panel to the foundation are commonly referred to as "Holdowns". Any vertical movement at this connection will show up as lateral movement at the top of the shear wall. With an aspect ratio of 1:1 (8' X 8') a 1/8" movement at the holdown will yield an 1/8" movement at the top of the wall. If a high aspect ratio wall is used, any movement at the holdown will be magnified at the top of the panel by that ratio. For example, if a tall narrow shear wall has an aspect ratio of 3.5:1 and the holdown moves 1/8" vertically the top of the panel would move horizontally 7/16". This movement is additive to all other movements, such as plate crushing, bolt slip, stud-nail slip, etc.

Some of the factors that may contribute to holdown movement are:

1. looseness of the stud bolts,
2. bearing of the holdown bolts into the stud,
3 eccentricity of the anchor bolt to the stud face resulting in holdown and/or stud bending.
4. flexibility in the seat of the holdown,

Test objective

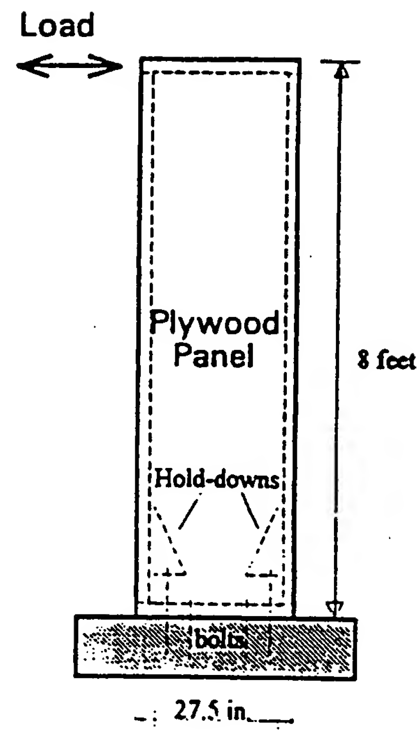
This test series had the following objectives:

a: Test walls dynamically with a large number of cycles (100 +/-) to observe and record the assembly performance at 100% and 140% of the typical design loads.

b: Compare three types of Holdown Devices. A special heavy HD5A, an HD5, and a special low deformation product called the nailed "rod-strap". The nailed rod strap is shown in figures 6 and 7.

c: Compare wall performance as shown by top of wall drift when cycled at a fast and slow rate (2 cycles per second vs. (15 seconds per cycle).

d: Determine Failure modes



Test Set-Up

As shown in drawing #A the shearwall panel measured 27-1/2" wide X 96" tall. It consisted of a nominal 2" X 4" Douglas Fir top plate (two) a single bottom plate, and 2 ea. 2 X 4 studs on each side nailed together, and a single stud in the center. All the nailing was per the Uniform Building Code with 16d green vinyl sinkers. To this frame a single 3/8" APA Structural 1 plywood panel was nailed. Diaphragm nailing consisted of 10d X 2-1/8" "Plywood Nails" spaced 4" on center on the edges and 12" on center in the field.

Figure A

According to the UBC Table No 25-K-1[3] the above combination will give an allowable loading of 990 lbs. (360 X 12/27.5 X 1.2) for the assembly. (Note that no additional value is given for the 10d nails used Vs the 8d specified.)

Observations

1 At a wall loading of 100% (985 lbs.) the movement of the HD5A holdown was consistently less than 0.108". This 985 lb. wall load translated into a holdown load of 4,500 lbs. The 4,500 lbs is 121% of the HD5A rated design load (3,705 lbs.).

2. No walls performed within the code proscribed .480" drift limit.

3. The wall connected with a rod-strap provided virtually no movement at the wall base joint. Even with a zero movement connection, the deflection at the top of the wall was 0.705". This movement exceeded the h/200 code limit by 46%.

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3 Uniform Building Code, UBC 1991, International Conference of Building Officials, Whittier, California

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4. The performance of the walls, as measured by the drift at the top of the wall, deteriorated with each cycle.

5. In all cases the failure mode was a bending and rebending of the plywood nails. This led to a fatigue failure of the nails about 3/8" below the surface of the wood stud. Figure #10 shows the wall at the end of the test. The nails are broken and ready to fall out. Figure #4 shows the fatigued and broken nails.

6. Although the information is not conclusive, it appears the fast and slow cycle rates (2 cps and 15 sec./ cycle) yield similar results.

Acknowledgments

The testing was performed in the Structures Test Hall of the University of California, Irvine on December 16, 1993. The facilities were arranged for by Dr. Robin Shepard. Special thanks go to Mr. Robert Kazanjy P. E. and his student crew who labored for hours and hours late into the cold night to set-up and run the tests.

Attachments:

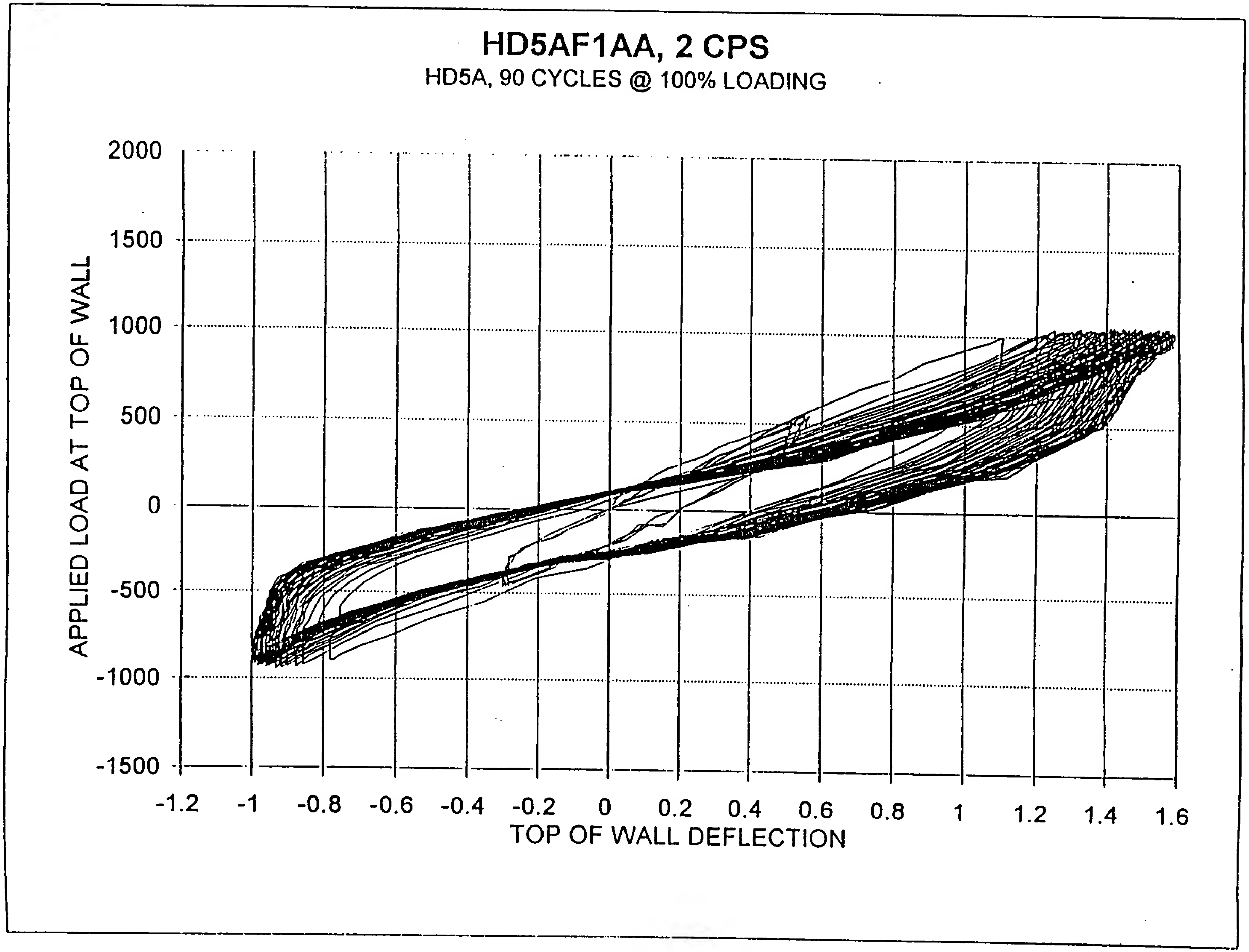
Graphs

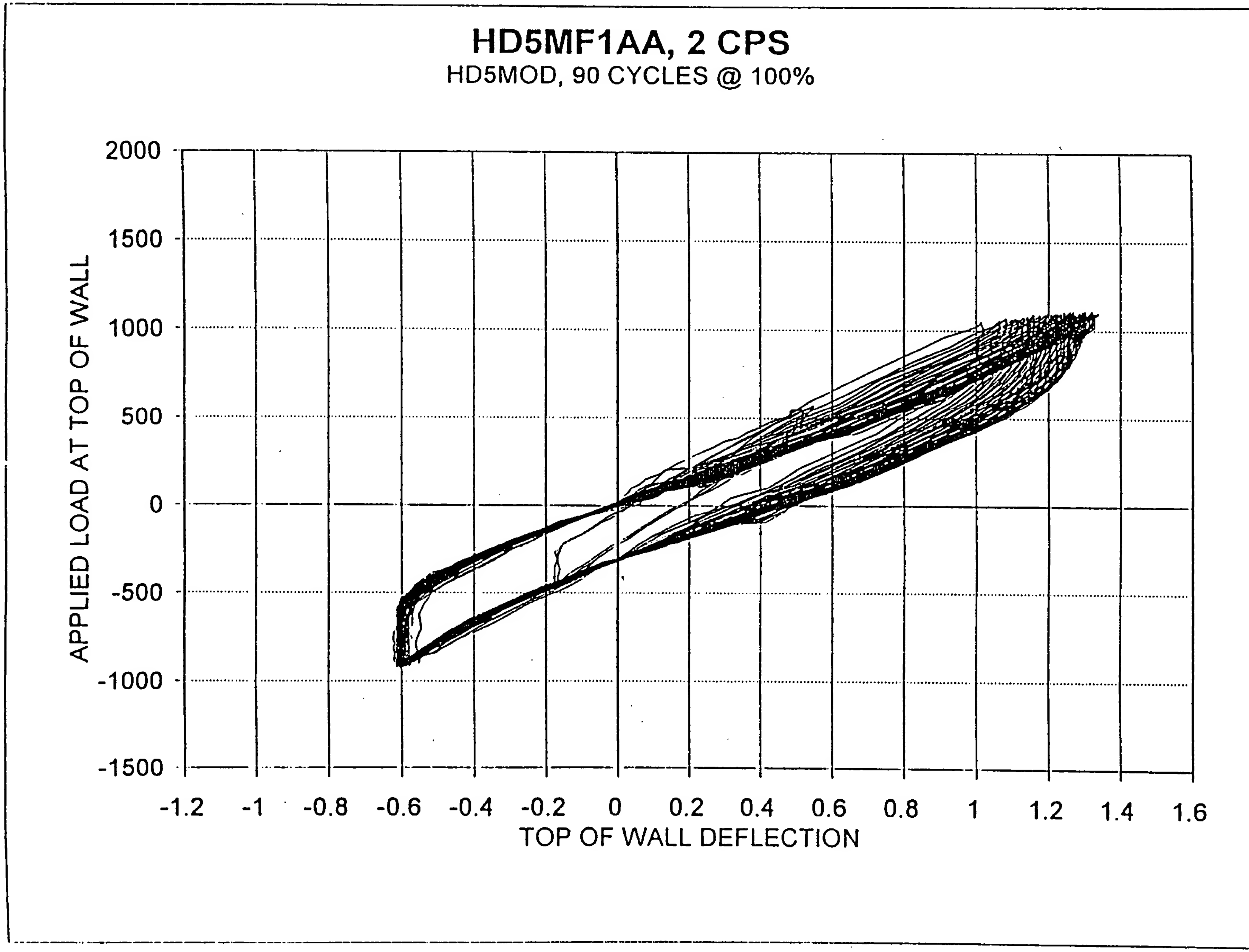
HD5AF1AA	HD5A, 2 cps, 985 lbs, 90 cycles.
RODF1AA	3/4" Rod Strap, 2 cps, 985 lbs, 90 cycles.
HD5MF1AA	Modified HD5, 2 cps, 985 lbs, 90 cycles.

Photographs

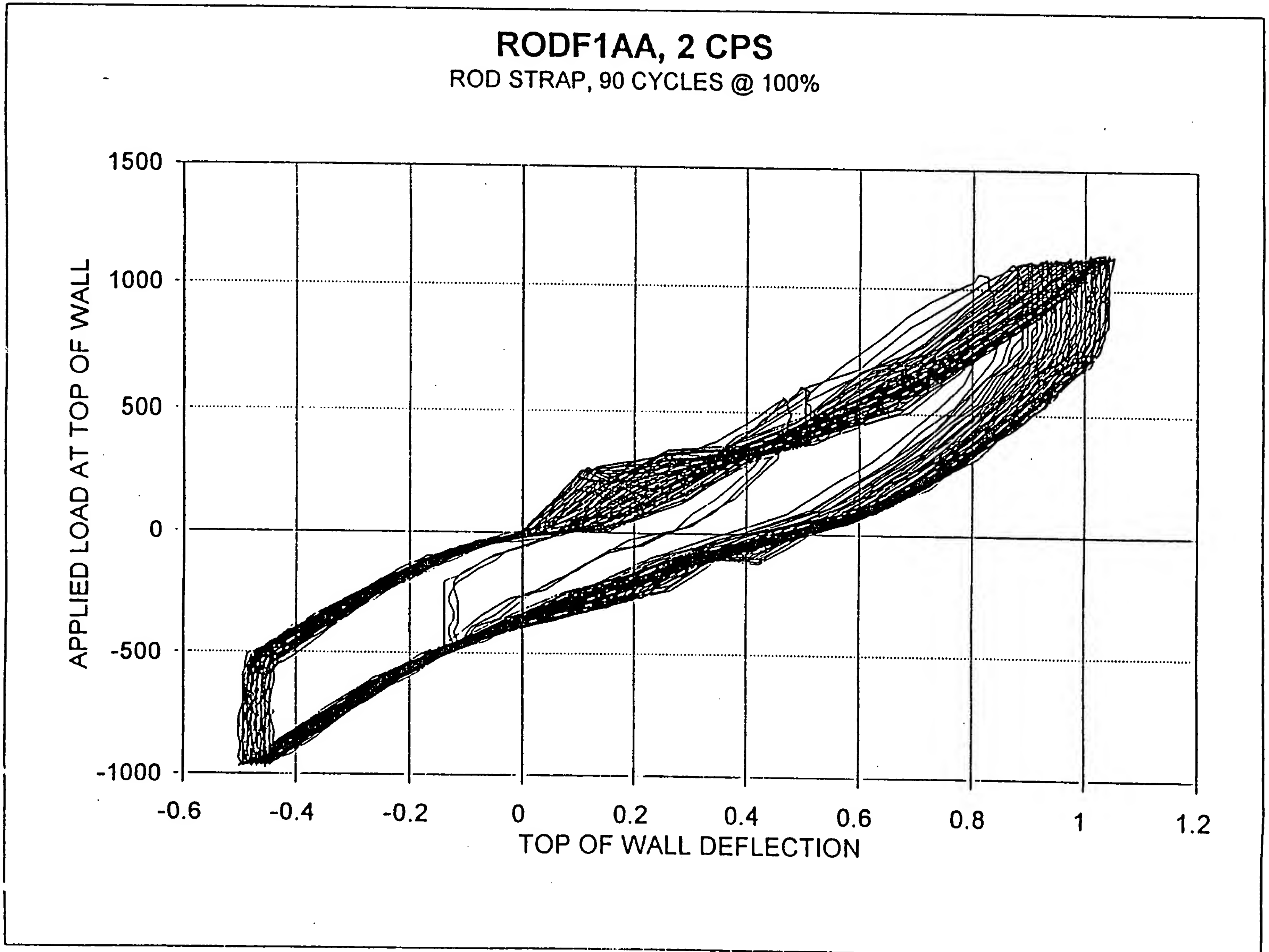
Figure #1.	Instrumented HD5A
Figure #2	A special Instrumented HD5
Figure #3	A Special welded-Nailed "Rod Strap"
Figure #4	Panel failure mode. Nails fatigued and fractured 3/8" below the stud-plywood interface.

The full report is available from Simpson Strong Tie Co. (510) 460-9912, ext. 921.


HD5AF1AA, 2 CPS
HD5A, 90 CYCLES @ 100% LOADING
APPLIED LOAD AT TOP OF WALL
2000
1500
1000
500
0
-500
-1000
-1500
-1.2
-1
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
TOP OF WALL DEFLECTION



HD5MF1AA, 2 CPS
HD5MOD, 90 CYCLES @ 100%
APPLIED LOAD AT TOP OF WALL
2000
1500
1000
500
0
-500
-1000
-1500
-1.2
-1
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
TOP OF WALL DEFLECTION


RODF1AA, 2 CPS
ROD STRAP, 90 CYCLES @ 100%
1500
1000
500
0
-500
-1000
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1
1.2
APPLIED LOAD AT TOP OF WALL
TOP OF WALL DEFLECTION

C1

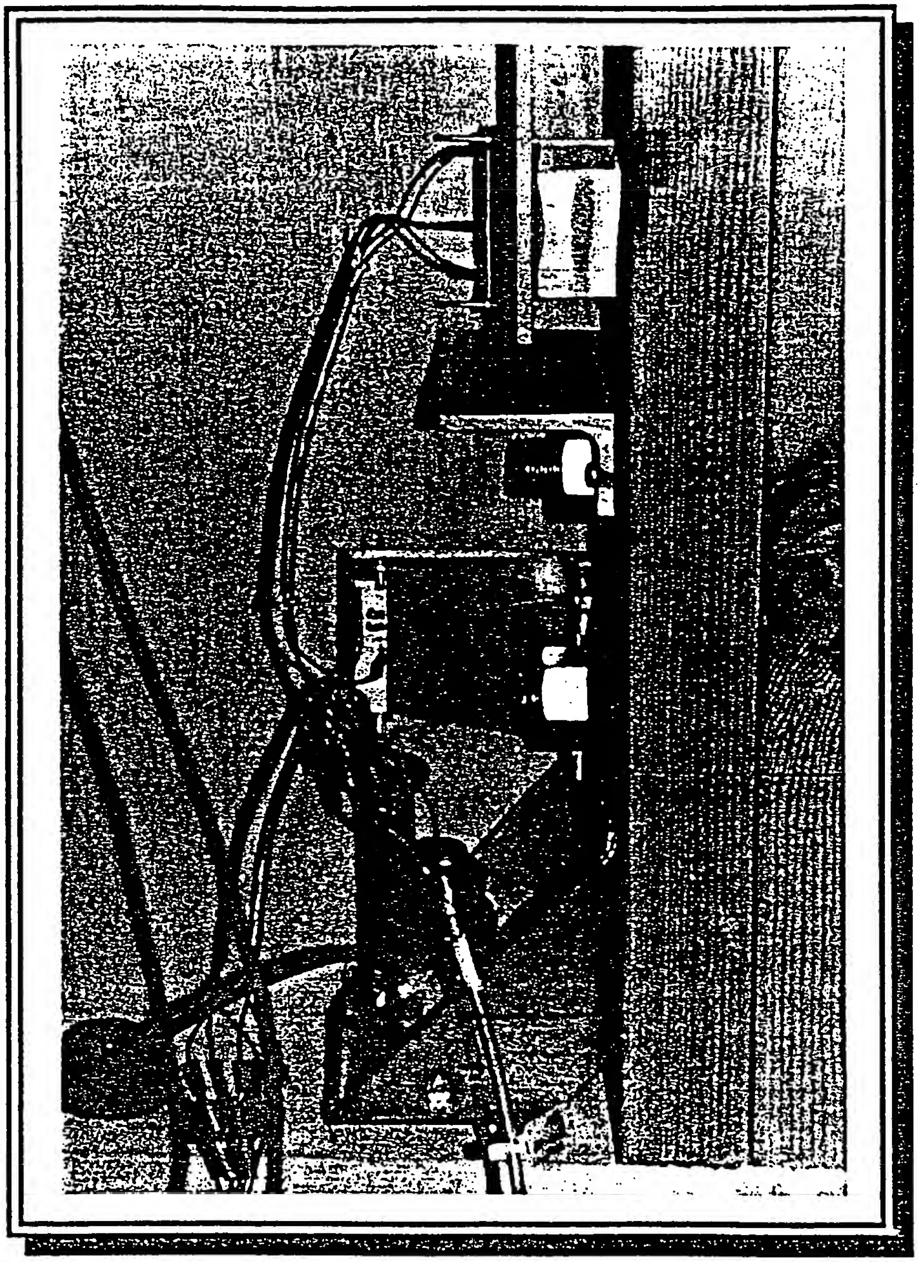


Figure #1
Instrumented HD5A

C1

Figure #2
A Special Instrumented HD5

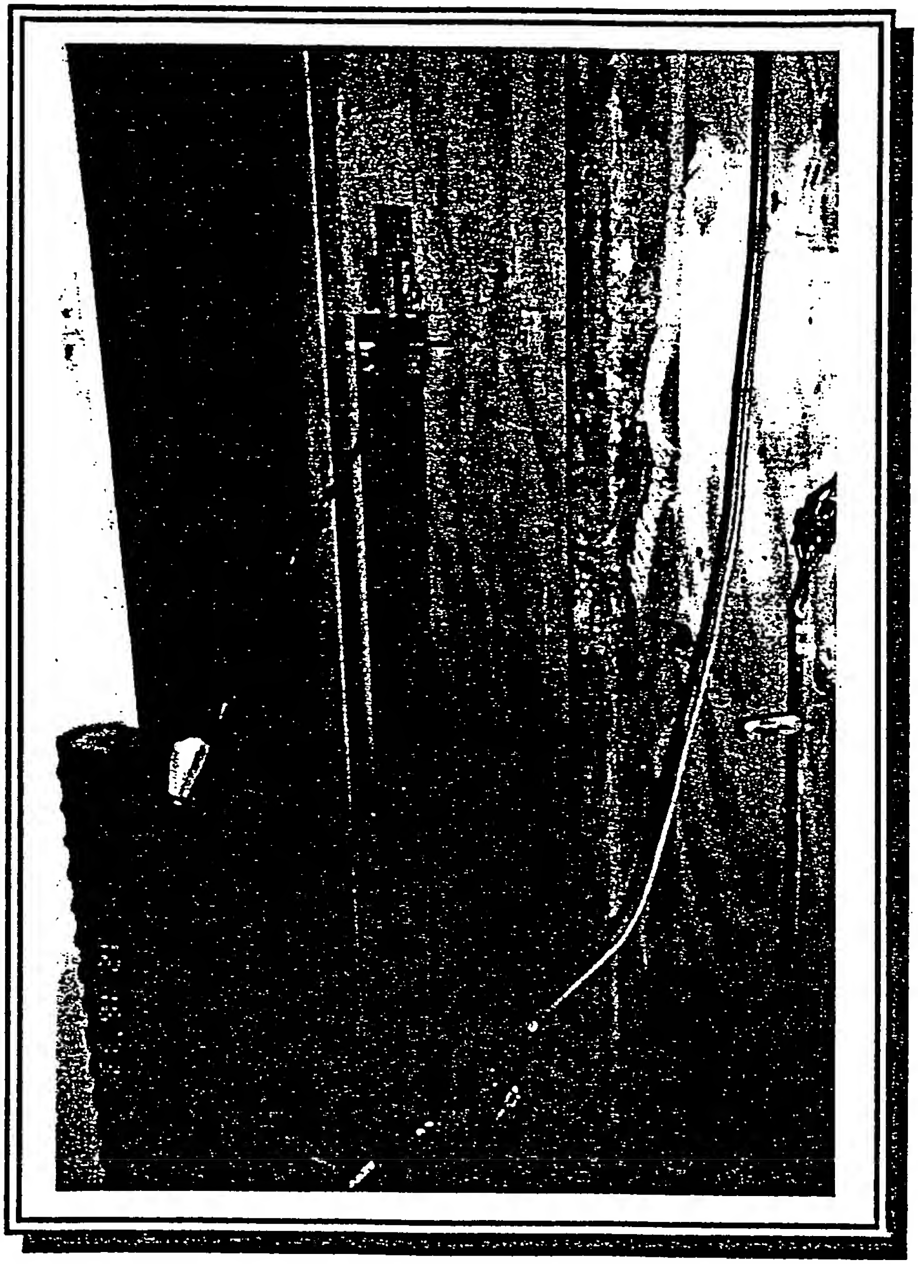


Figure #3
A Special Welded-Nailed "Rod Strap"